Available online at www.sciencedirect.com
ScienceDirect
Procedia Materials Science 5 (2014) 147 – 153
Procedia Materials Science
www.elsevier.com/locate/procedia

International Conference on Advances in Manufacturing and Materials Engineering, AMME 2014

Experimental Investigation of Al6061/Al_2O_3 Composite and Analysis of its mechanical properties on onshore wind tower using hybrid technique for Indian Condition

Pramod kumar Sharma[a], Vilas Warudkar[b], Siraj Ahmed[c]*

[a]*M.Tech Scholar, Maulana Azad National Institute of Technology, Bhopal (M.P), India*
[b]*Assistant Professor,Maulana Azad National Institute of Technology, Bhopal (M.P), India*
[c]*Professor, Maulana Azad National Institute of Technology, Bhopal (M.P), India*

Abstract

This paper seeks to analysis of Al6061/Al_2O_3 microstructure metal matrix, composites fabricated by ultrasonic stir casting technique, for different weight percentage of reinforcement.An experimental set up was prepared to facilitate the preparation of required MMCs The results obtained from the experimental set up are used to analyze the buckling effect of the tower. The tower is analyzed for different materials for steel, concrete and hybrid on ANSYS and the design parameters such as radius of gyration, thickness and base dimensions are optimized using simulation technique.The main objective of this paper is to explore more wind potential by measuring the wind data at 150m height and to locate a safe and economic tower at this location, it will produce more power output and would boost the economy of India in a very rapid manner which is the current major issue of our society.In order to locate a 50m wind monitoring tower to measure the wind characteristics, we investigated the site near Paradip, Odisha (India) to locate wind tower and collected some wind data to incorporate into the design of tubular steel tower. This paper seeks to understand the design of tubular steel tower and its performance parameter up to 150m height, also it provides the stability analysis such as static, buckling and vibration using computer optimized approach.

Selection and peer-review under responsibility of Organizing Committee of AMME 2014

Keywords: AMC; Buckling; MMC; Onshore; SEM; USC.

* Corresponding author. Tel.: +9691403272; fax: +0-000-000-0000
E-mail address: pramodvssikandar@yahoo.co.in

Selection and peer-review under responsibility of Organizing Committee of AMME 2014
doi:10.1016/j.mspro.2014.07.252

Nomenclature

$\sigma^{buckling}$	=	buckling stress
fy	=	yield stress
Es	=	elasticity of modulus
t_w	=	wall thickness
r_m	=	mean wall radius
$\sigma^1,\sigma^2,\sigma^{3,}$	=	principle stress acting on the tower section
V_b	=	basic wind speed in m/s
Vz	=	design wind speed at any height z
P_d	=	design wind pressure
$K_1,K_2,K_3,K_4,$		
Ka,Kd,Kc	=	factors taken from IS:875 code
Fs	=	factor of safety

1.0 Introduction

As per the International Electro technical Commission (2007), if we increase turbine elevation from 80 m to 100 m, it will give 4.6% larger wind speed and a 14% increased power output. Similarly, an increase from 80 m to 120 m would result in an 8.5% greater wind speed and a 28%increase in power production. Brughuis et. al, 2004 had suggested the criteria to install few more higher tower compare to larger small tower . G.B. Veeresh Kumar et al. (2013) the composites of Al6061 containing 2–6 wt% SiC were prepared using liquid metallurgy route. The experimental results showed that the density of the composites increase with increased SiC content and agrees with the values obtained through the rule of mixtures. The hardness and ultimate tensile strength of Al6061–SiC composites were found to increase with increased SiC content in the matrix at the cost of reduced ductility. The wear properties of the composites containing SiC were superior to that of the matrix material.N. Hosseini et al. (2012)Investigated the wear behavior of nanostructured Al6061 alloy and Al6061–Al_2o_3 nano composites produced by milling and hot consolidation. The samples were characterized for hardness test, pin-on-disk wear test, and scanning electron microscopy (SEM). Nano composites containing 3vol% Al_2o_3 showed a maximum hardness of 235HV and optimum wear rate of 4103 mg/m. Increasing the amount of Al_2o_3 up to 5vol% resulted in decrease in hardness values(112 HV) and a sharp rise in wear rate (18103 mg/m).G. G. Sozhamannan et al. (2012) Al-11Si-Mg /Sic metal matrix composites were fabricated by different processing temperatures with different holding time to understand the influence of process parameters on the distribution ofparticle in the matrix and the resultant mechanical properties. The particles were distributed uniformly in the processing temperature 750°C and 800°C. The particles agglomerations were found in the processing temperature of 700°C, 850°C and 900°C due to the changes of viscosity in liquid Al matrix. Ultimate strength in-creased gradually up to 800°C and starts to decrease. The Ultimate strength of metal matrix composite de-creases with increasing holding time.C.S. Ramesha et. al. (2007) investigating the wear behavior of hot extruded Al6061 based composites. SiC, Al_2o_3 and cerium oxide have been used as the reinforcements. Composites have been primarily processed by vortex method(stir casting). The cast composites have been subjected to hot extrusion at a temperature of 550 .Extruded component possess higher micro hardness and wear rates under all studied loads and sliding velocities when compared with cast composites.As per LaNier et. al (2005), the total cost for a 3.0 MW, (120 m) tower is $3,445,150. Out of that $551,415 is associated with the tower materials and $195,160 is associated with tower transportation, which is near about 21.7% of the total cost of each wind turbine. IS:875 code is used to calculate design wind speed upto 150m height, it can be further extended to more than 150m height also. A. Quilligan et.al has worked on the Fragility analysis of steel and concrete wind turbine towers. Burton et. al had given the local buckling criteria. Ugural et.al given the failure theory in ductile material. P.E. Uysa et.al also worked on the cost minimizing approach of steel shell tower. Maalawi KY et.al had given stiffness maximizing approach. Ugural and Fenster et.al had the stress tensor matrix approach at the critical section of the tower.

2.0 Experiment Setup

For performing the experiment & testing of composites following machine/equipments are required.The problem is associated with the study of effect of cold press forging and hot press forging on various properties and distribution of Al6061/ Al_2o_3 metal matrix, composites fabricated by ultrasonic stir casting technique, for different weight percentage of reinforcement.An experimental set up was prepared to facilitate the preparation of required MMCs. The aim of the experiment was to study the effect of secondary forming process and variation of the percentage composition to predict the different properties of the final composite product. The experiment was carried out by preparing the samples of different percentage composition before and forging and then subjected to different machines such as Hardness testing machine, Universal testing machine, SEMetc, to check the behavior of the composites before and after forging.

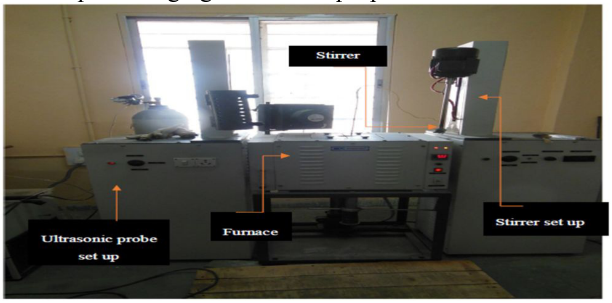

Fig.01-Stir Casting Set-up

- Weighing Machine
- Matrix (Al 6061 alloy)
- Reinforcement(Al2O3)
- Crucible(Graphite)
- Mould(Mild Steel)
- Stirrer
- Ultrasonic Probe
- Forging die
- Polishing machine
- Press forging machine
- Rockwell Hardness Testing Machine
- Universal Testing Machine
- Lathe

- Scanning Electron Microscope (SEM)

Fig.-02- Ultrasonic transducer and Ultrasonic transducer set up

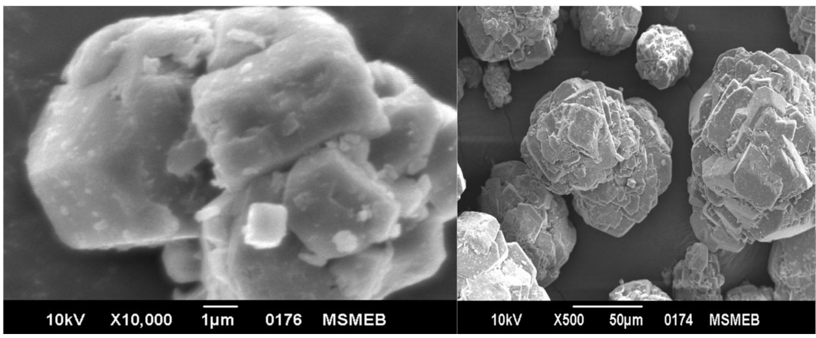

Fig.-03. SEM images of Al_2O_3

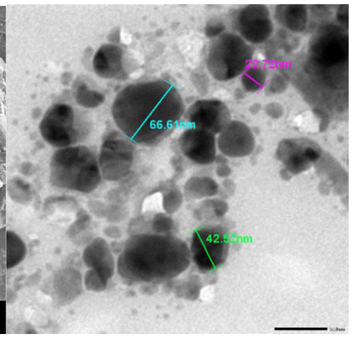

Fig.-04- TEM images of Al_2O_3

- Transmission Electron Microscope

2.0 Methodology

The allowable local buckling stress method involves-
1) Calculating the elastic critical buckling stress of a cylindrical steel tube, which has modulus of elasticity Es, wall thickness t_w, and mean radius r_m, in axial compression.
2) Calculating critical stress reduction coefficients for bending and axial Loading.
3) Plugging these values along with the material's yield strength f_y to obtain the allowable local buckling stress. The maximum principal stress in the structure should not exceed this allowable local buckling stress value in order to avoid local buckling.

2.1 Assumptions

- Tower is assumed as a cantilever beam with linear varying cross-section and thickness, concentrated as a point mass (Weight of tower, instrument, 20% margin) acting at the top end.
- Material is to be following Hook's law of elasticity.
- Euler-Bernoulli theory is used in buckling analysis.
- Neglecting the effect of drag force caused by air flow.

Burton et.al given the local buckling criteria

$$\sigma^{buckling} = fy\ 1 - 0.4123\ \frac{fy}{\alpha^b.\sigma^{cr}}^{0.6} \quad ,\alpha^b.\sigma^{cr} > \frac{fy}{2} \tag{1}$$

$$0.75\alpha^b.\sigma^{cr} \quad , \alpha^b.\sigma^{cr} \leq \frac{fy}{2} \tag{2}$$

$$\sigma^{critical\ elastic} = 0.605\ Es\ \frac{tw}{rm} \tag{3}$$

$$\alpha^b = 0.1887 + 0.8113\alpha^o \tag{4}$$

$$\alpha^o = \begin{cases} \dfrac{0.83}{1+0.01\frac{rm}{tw}}, & \dfrac{rm}{tw} < 212 \\ \dfrac{0.70}{0.1+0.01\frac{rm}{tw}}, & \dfrac{rm}{tw} \geq 212 \end{cases} \tag{5}$$

The maximum distortion energy theory states that yielding will occur when the distortion energy per unit volume is equal to that associated with yielding in a simple tension test. This theory is commonly used in engineering design because of its proven track record for predicting failure in ductile Materials. Principal stresses σ^1, σ^2 and σ^3 are obtained at the critical points in the tower. In practice, an appropriate factor of safety fs, is applied to reduce
the material's yield stress σ_{yp}.

Ugural et.al given the maximum distortion energy theory for ductile material,

$$\sigma^1 - \sigma^2\ ^2 + \quad \sigma^2 - \sigma^3\ ^2 + \quad \sigma^3 - \sigma^1\ ^2 = 2\ \frac{\sigma^{yp}}{Fs}^2 \tag{6}$$

Total weight assumed on the tower,
=Weight of the tower +weight of the instrument+20%with the weight of the instrument,
As per IS: 875,

$$Vz = V_b * k1 * k2 * k3 * k4, \tag{7}$$

The design wind pressure P_d can be obtained as,

$$P_d = 0.6 * K_d * K_a * K_c * V_z^2, \tag{8}$$

3.0 Results

Hardness Testing Machine Model- TRSN-D/TRSNT-D (as shown in figure) Iis used. Rockwell cum Superficial test is an indentation hardness test using a verified machine to force a diamond spheroconical indenter or hard steel ball indenter under specified condition into the surface of the material under test. In design, mechanical properties such as elastic modulus and yield strength are important in order to resist permanent deformation under applied stresses. This test is also performed on a Universal Testing Machine. In this test the specimen is placed between the table and moving cross head. After the test, final diameter and the length is measured.A little consideration will show that due to the compressive load, there will be an increase in cross section area and decrease in length of a body. The ratio of the decrease in length to the original length is known as compressive strain.

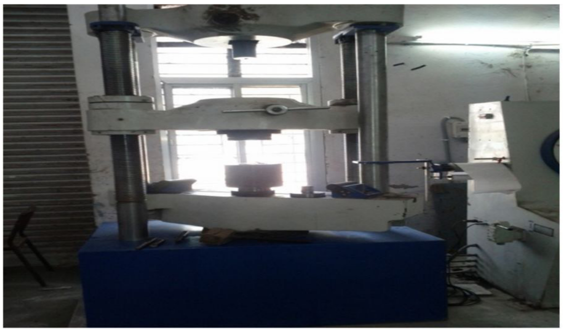

Fig. 05- Universal Testing Machine

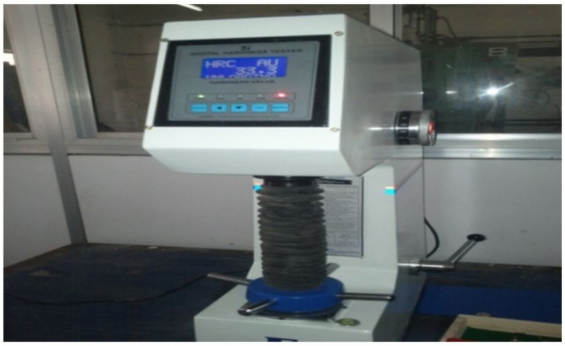

Fig. 06- Hardness Testing Machine

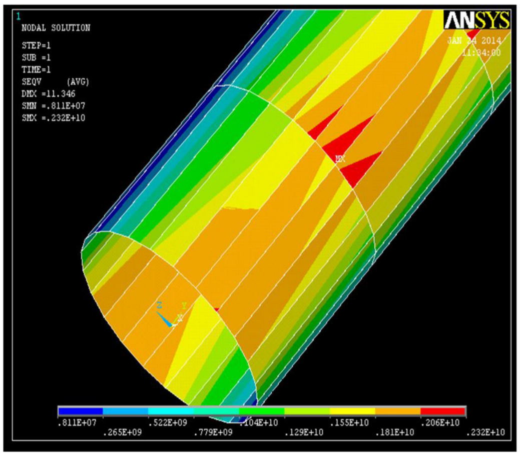

Fig.07- Von Misses result for steel tower

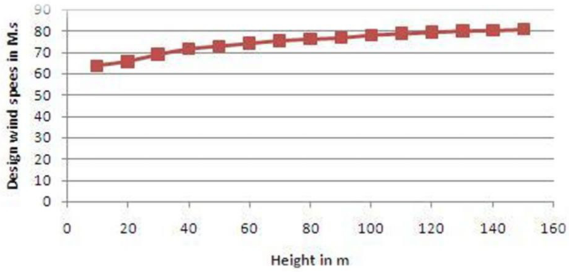

Fig.08- Design wind speed variation with respect to height

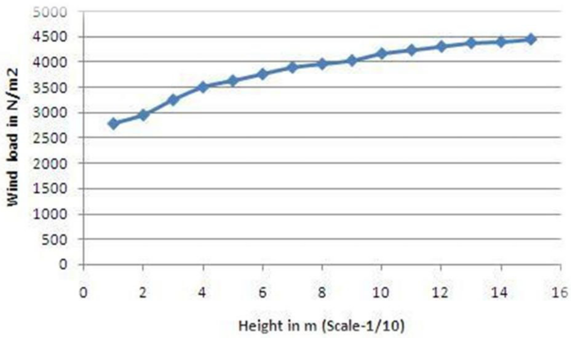

Fig.09- Design wind load variation with respect to height

Fig.09 and Fig. 08 shows the distribution of design wind pressure and wind speed with respect to height. The analysis is done on ANSYS using Shelll element with linear variation of thickness assuming the cantilever beam with one end fixed. The Von misses result shown in fig.07 indicates that maximum stress acting on the bottom section of the tower is much below the the failure strength of the tower for all the type of material.The buckling results are displayed which shows that concrete has more severe to buckle compare to steel and hybrid material.

Table 1- 5 modes of buckling for steel tower

Set	Time/Freq.	Load Step	Sub Step	Cumalative
1	4.8297	1	1	1
2	6.0758	1	2	2
3	7.0880	1	3	3
4	7.6772	1	4	4
5	7.6772	1	5	5

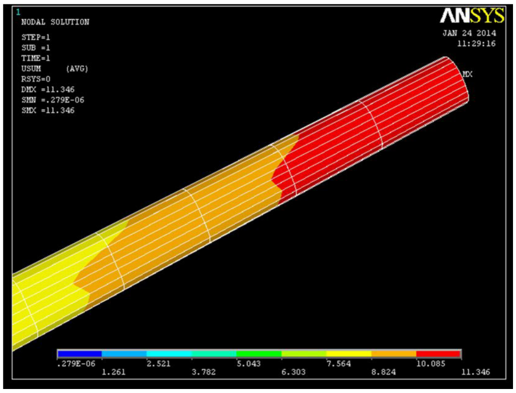

Fig.10 -Total mechanical strain for steel tower

Table 2.-5 modes of buckling for concrete tower

Set	Time/Freq.	Load Step	Sub Step	Cumalative
1	0.46302	1	1	1
2	0.58166	1	2	2
3	0.67829	1	3	3
4	0.76601	1	4	4
5	0.76902	1	5	5

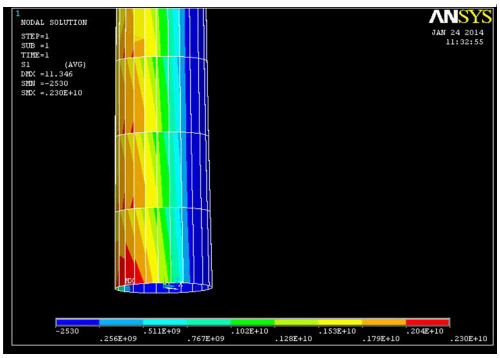

Fig.11- 1st Principle Stress for steel tower

Table 3.- 5 modes of buckling for hybrid tower

Set	Time/Freq.	Load Step	Sub Step	Cumalative
1	4.8297	1	1	1
2	6.0758	1	2	2
3	7.0880	1	3	3
4	7.6772	1	4	4
5	7.6772	1	5	5

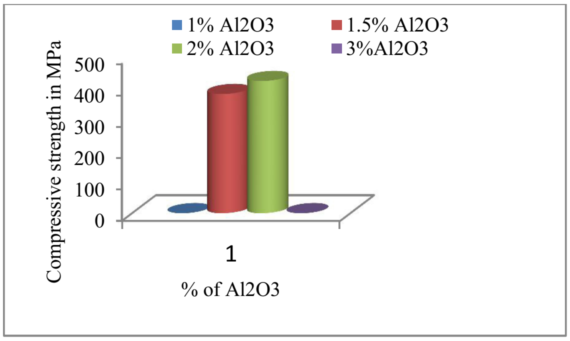

Fig. 12-Compressive strength variation

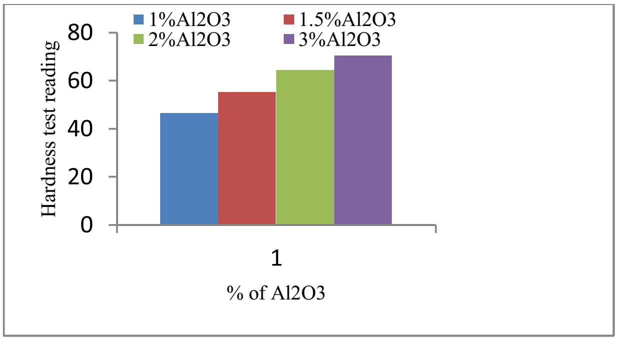

Fig.- 13 Hardness test reading

Table 4 Hardness test reading

Set	1	2	3	4	5	Avg.
1% Al_2O_3	47.7	46.1	48	44.1	46.3	46.44
1.5% Al_2O_3	51.5	54.4	55.3	56.8	58.1	55.22
2% Al_2O_3	64.1	64.3	68	62.8	63	64.46
3% Al_2O_3	71.2	70.3	72.1	69	69.7	70.46

Table 5 Compressive test reading

Set	Compressive strength (MPa)
1% Al_2O_3	354.80
1.5% Al_2O_3	379.15
2% Al_2O_3	420.40
3% Al_2O_3	398.31

Conclusion

The present work on preparation of 6061Al-Al_2O_3 metal matrix composite by ULTRASONIC ASSISTED STIRR CASTING and evaluation of mechanical properties has led to following conclusions:-

- Aluminium based metal matrix composites have been successfully fabricated by ultrasonic assisted stir casting technique with fairly uniform distribution of aluminium oxides particulates.
- It reveals that the hardness of composite increases with increasing the weight percentage ofAl_2O_3 particles.
- Further, when wt. % of nano Al_2O_3 exceeds 2%, compressive strength decreases. This because of clustering/agglomeration of nano particles at higher weight % of Al_2O_3.
- Ultimately, this paper provides the overall design of onshore tubular steel tower at Paradip port situated at the confluence of river Mahanadi and Bay of Bengal.
- Due to limitation of transportation it is difficult to manufacture steel plates more than 4.3 m. So, research is needed to improve the manufacturing technology in steel sectors and design of towers in such a way, so that the better utilization of steel could be done which is the current major issue in front of researchers and scientists.
- Research is also needed to incorporate the use of hybrid towers instead of steel for the tower height exceeding 100m. Tower dimensions were determined by the combination of strength and fatigue. As such, the tower's operational design life is approximately 35 years.

Acknowledgment

In this paper a lot of contribution is given by the team members of the Paradip refinery project at Odisha (INDIA).

References

A.Quilligan et.al. 2012. Fragility analysis of steel and concrete wind turbine towers, Engineering structure, ELSEVIER.

Burton et.al. 2001. Wind Energy Handbook. West Sussex, England: John Willey & Sons ltd.

C.S. Ramesha et al. (2007), "Wear behavior of hot extruded Al6061 based composites", Wear 263 (2007) 629–635

G. B. VeereshKumar et al. (2010), "Studies on Al6061-SiC and Al7075-Al2O3 Metal Matrix Composites", Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.1, pp.43-55, 2010.

G. G. Sozhamannan et al. (2012), "Effect of Processing Paramters on Metal Matrix Composites: Stir Casting Process ", Journal of Surface Engineered Materials and Advanced Technology, 2012, 2, 11-15.

Lanier, M.P.2005.LWST phase I project conceptual design study-Evaluation of design and construction approaches for economical hybrid steel/concrete wind turbine towers, Golden: NREL.

Maalawi KY.Structural design optimization of wind turbines.Cairo.University, 1997.

N.Hosseini et al. (2012), "A comparativestudyonthewearpropertiesofcoarsegrainedAl6061alloy and nanostructured Al6061–Al2O3 composites", Tribology International 54: 58–67.

P.E.Uysa et.al. 2006. Optimization of a steel tower for a wind turbine structure, ELSEVIER, Engineering structure.

Ugural.et.al., 2003.Advanced strength and applied elasticity, 4th edition. New Jersey-Prentice Hall.

Wind load Calculation for Building IS: 875.